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PERLITE, SOURCE OF SYNTHETIC PUMICE

BY

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PERLITE, SOURCE OF SYNTHETIC PUMICE[1/]

By Oliver C. Ralston[2/]

INTRODUCTION

The growing popularity of perlite (sometimes spelled pearlite) as a raw material for thermal expansion into pumicelike products in the Western States has prompted a preliminary investigation of the properties of such material and the problems that want solution to put a perlite industry on a firm foundation. The Bureau of Mines is undertaking the gathering of data and the solution of these problems, and the following paper records some of the available information and the promise of the material, with some comparisons of advantages of the various competing lightweight aggregates that can be made from siliceous volcanic glasses and rocks containing entrapped or dissolved water that causes their expansion on quick heating to their softening points.

This new industrial rock has caught the fancy of the mineral industry in the Western States because it has some advantages over natural pumice. Chemically, it is typified as rhyolitic in composition, and one may find obsidian, rhyolite, pumice, pumicite, and perlite from the same vant and contemporaneous in origin. The material need not be rhyolite but should be a siliceous or acid lava and contain 2 to 5 percent water still in "solution" in the rock. On quick heating to the softening temperature the material puffs, due to conversion of the contained water into bubbles of steam. Slow heating causes gradual release of the imprisoned water by decrepitation and cracking and results in very little puffing. Perlite is often in the form of ovoid volcanic bombs formed by explosive eruption of large masses of lava into the air, where they quickly cool, with escape of little of the contained water, except perhaps for a hollow interior. Since they cool in layers they have an onion-type structure and a pearly luster from interference of light between the layers, which is the origin of the name "perlite." Perlite may occur in intruded flows that have been quickly cooled and partly expanded but retained most of their magmatic water content. Obsidian may be the same lava cooled quickly under conditions that prevented crystallization of feldspars and other minerals, leaving the volcanic glass that may or may not retain all of the original contained water.

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Pumice is merely the lava foam that forms on reaching the surface of the earth with release of pressure, resulting in partial release of water in the form of steam bubbles that remain entrapped in the "molasses." Pumice has been used for many years as a lightweight aggregate in concrete and other cementatious materials and articles. All of the known uses of pumice and pumicite (volcanic ash) can be filled by perlitic products and by control of firing conditions some degree of control over the degree of puffing, bubble size, wall thickness, bulk density, and crushing strength can be attained. Most natural pumice is used in the condition that nature made it, and to get various strengths of aggregates one switches from one pumice deposit to another and too often the best pumice occurs in remote places. The attractiveness of perlite comes from the degree of control of porosity and strength. However, Cannon (3)3/ has pointed out that a pumice also contains unreleased water and will expand further on heating and can have its surfaces glazed to close the bubbles against water penetration when the heat-treated granules are used as an aggregate in a concrete. The same is true of pumicite, which can sometimes be expanded into very tenuous balloons (10).

It may be concluded that, as an industrial mineral, the definition of perlite must be expanded beyond the rather rare form of acid lava given that name by the petrologists. It is any siliceous lava containing dissolved water in sufficient amount to expand into bubbles when the material is quickly heated to a suitable point in the softening range. A material of sharp melting point and therefore very short softening range is not desirable because the degree of puffing will be less controllable.

HEATING OF PERLITE

Quick heating is essential to get usable expanded perlite products. Tests on a wide variety of siliceous lavas of suitable water content, made in the Bureau of Mines laboratories at Salt Lake City, Utah, Rolla, Mo., Boulder City, Nev., and Tucson, Ariz., have shown that when in granular form and not over ¼ inch in diameter only 1 to 3 minutes exposure to the proper temperature is required. The suitable temperature range for puffing must be determined for each raw material and will vary from 1,600° to 2,600° F. If heated only to the lower end of the temperature range, the material will be only slightly puffed and therefore have low bulk density but high strength. The expansion is greater when the material is heated to higher temperatures and is greatest near the point where it tends to become molten. If the material is heated to the point where it can partly liquiefy, gas escapes and the granule shrinks. If fully melted, all gas will ultimately escape and dense slag is the result.

The problem from the technologic standpoint is to develop means of heat treatment that will permit formation of expanded granules of all degrees of bulk density, crushing strength, and other physical properties.

3/ Numbers in parentheses refer to items in the Bibliography at the end of this circular.

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The steam bubbles are preferably left completely trapped and with no openings to the exterior. For some uses this may not be true, but they are exceptional The expansion of the softened material normally causes opening of cracks that can be penetrated by water if the granules are used in a concrete aggregate. One problem in heat treatment is to momentarily superheat only the exterior of the granules in order to seal the surface against all intrusion by liquids or gases.

The simplest furnace for continuous heating of perlite granules to the proper temperature range is the rotary kiln like a cement kiln (13). Countercurrent flow of the hot gases and the perlite results in long residence in the kiln and slow heating. Therefore the successful kilns are those with cocurrent flow. The perlite is fed into the kiln at the hottest point and is at once heated. The burner is placed at the feed end, and a chimney is needed tall enough to draw the gases down the gentle slope of the kiln to the discharge end. A very short kiln is needed because cocurrent flow of gas and material has no opportunity for heat exchange. Such a kiln subjects the material at once to the highest temperature in the kiln and cannot be used to momentarily flash the granules to a higher temperature to seal pores by heating only the outer surface. Little exists in the literature about suitable furnaces, but Moorman (14) has patented one. Gladney (10), in discussing the suitability of the rotary kiln for further expanding pumice and pumicite, speaks of forming a glassy exterior at the same time that gases are causing swelling within. Whether this double objective can actually be realized is questionable. A finished, expanded perlite or a natural pumice granule heated slowly in the kiln to vent all residual gases could reach a temperature of glass formation on the exterior of the granules, but this would require very exact temperature control to prevent too deep vitrification. Gladney states that the motion of the material in the kiln prevents its sticking together, but in view of the usual behavior of rotary kilns when clinkers reach a temperature where the where the surface can run this claim remains to be substantiated.

The sealing of surfaces probably can be done best on finished granules dropped through a zone at a suitable closely controlled temperature, followed, if necessary, by immediate quenching in liquid or cool gases to freeze the glass to a point where particles cannot stick together when they meet. Either fuel heating or electric heating might be used. This is only one of the problems proposed for research by the Bureau of Mines.

Many perlites contain masses of material that will not expand or that escape complete expansion. Where the granules are light enough to float on water, these unexpanded granules can be separated by allowing them to sink. The wet material drains easily because most of the pores and cracks are closed.

BULK DENSITY

The weight per cubic foot of closely sized granules of expanded perlite and related products is the datum most frequently discussed. The Bureau of Mines has heated perlites and obsidians from a variety of places, mainly in

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Arizona, Nevada and California. The different materials expanded to as little as 5 pounds per cubic foot; many of them showed 10 to 30 pounds per cubic foot, and some of them had varying expansions from zero to proportions that gave granules between 30 pounds and the weight of the original raw material. There is probably a place for material from the lightest possible granule to material weighing as much as 40 pounds, depending on the use to which it is to be put. For loose-fill thermal insulation the 5- to 10-pound material can probably compete with vermiculite. Concrete that must bear considerable load would require material of higher crushing strength and hence of higher weight (lower bulk density). Concrete required to carry low loads and used mainly as thermal or sound insulation could use the fragile high-bulk perlite.

Whether high-strength intermediate-bulk material can be made by partial firing of a perlite that can normally expand to very high bulk density is not known. It is one of the problems for research. However, the majority of perlites give granules of intermediate bulk density, and there will be more of them suitable for lighweight strong concrete than there will be of those suitable for the best low-load thermal insulation.

CRUSHING STRENGTH

Very little is known about the actual crushing strength of the various grades of perlite. The material weighing only 5 pounds per cubic foot is fragile and tenuous but may well prove to be stronger than vermiculite of the same bulk density on account of its cellular constitution. Crushing strength in a concrete or in a gypsum wallboard is of greater importance, and considerable research is needed on the usual concrete test forms. The perlites can be expected to vary in size of gas bubbles and thickness of the inclosing cell walls and therefore to vary in crushing strength for the same bulk density. Collection of data on this subject is an attractive subject for research that remains to be done and will serve more to expand the market for the material than any other thing that might be done by the technologist. Obsidian from near Glass Mountain, Little Lake, Inyo County, Calif., was observed by H. G. Poole, of the Salt Lake Station of the Bureau of Mines, to have smaller gas bubbles than any of the perlite samples from that locality (unpublished data). Gladney (10) states that the expanded product formed by further calcination of pumice granules is superior in strength and only one half to three quarters the weight per cubic foot.

THERMAL INSULATING VALUE

A porous aggregate is certain to have good thermal insulating value. The data on coefficient of thermal transmission should be determined on a variety of perlite products of varying bulk density and of varying steam-bubble diameter. No information of this kind is available at the moment, but a number of claims (7) are made that the insulating value is superior to a number of other substances. When these claims are made, the physical description of the perlite used is missing.

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MOISTURE CONTENT

The trapped moisture content of a siliceous lava is an indicator of the probable utility and properties of the material. Wilson (25), in defining perlite as a siliceous volcanic glass containing 2 to 5 percent of bound or entrapped water, adds some information on the water content determined by loss on igntion of samples dried at 110° C. in the drying oven. He has measured the following water contents:

	Percent
Obsidian.....	0.63
Phyolitic perlite	2.94
Dacitic perlite..	2.92
Andesitic perlite	2.43
Pitchstone.....	6.48

Wilson had not determined this datum for vitrophyre, tachylite, pumice, or glassy tuffs which, he says, expand in the same way. Any one of these perlites will vary in the amount of contained water, and it may well prove that the higher the amount of water entrapped the more the material will expand or the larger will be the individual bubbles. This point demands investigation, and it is believed that the water content will prove an important datum in describing a perlitic raw material.

PETROGRAPHIC EXAMINATION

The correlation of the various perlites, pumices, and pumicites with their behavior on expansion is worthy of inclusion in research on this subject. Petrographic examination of polished sections of the expanded materials is necessary in the correlation. The influence of mineralogical constitution, distribution, and grain size on the size of bubbles and thickness of cell walls should be known.

USES

As mentioned earlier, perlite can compete with any of the uses of pumice or pumicite, and therefore this discussion can include the uses of those materials. Some of these uses have not been mentioned in the promotional literature on perlite. In general, they involve lightweight products, thermal insulation, acoustics or sound insulation, and ceramic uses.

Ceramic Uses

The siliceous lavas that produce perlite and pumice are normally high in feldspars, particularly rhyolite. Cannon (3), Plummer (17), and Sergeeva (20), have all experimented with pumice fines as a substitute for feldspar in ceramic bodies where color is of minor importance in the finished product. From a perlite plant the fines formed in crushing the perlite to various-size granules might well be marketed in this manner. Plummer tested pumicite of Kansas origin for making glazes as well as using for the feldspar in ceramic

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bodies. About 50 percent more of the pumicite was needed for the ground feldspar that it replaced. Cannon's work on a California rhyolitic tuff showed that ceramic bodies would mature at cone 4 compared to cone 9 or 10 when feldspar is used. Sergeeva found shrinkage to be 1-1.5 per cent higher when ground pumice was used in place of feldspar.

Bricks and Shapes

Lightweight brick can be made of perlite or pumice by addition of the necessary binder clay and then firing, say Fitzgerald (9), D'Antoni and Ceccheti (8), and Solov'ev (21). Hicks (11) has patented a ceramic composition suitable for building block, roofing tile, sewer pipe, and the like, comprising 20 to 100 parts of pulverized perlite and 100 parts clay, thoroughly commingling them, and then adding a mixture of 30 to 100 parts of cellulose and enough water to make a plastic mass that may be handmolded, dried, and heated to not over 450° F. Romberg (18) states that obsidian can be smelted in a shaft furnace and the frothy slag issuing therefrom rolled or pressed into shapes or, after cooling, be mixed with cement, lime, etc., to make shapes. It is doubtful if Romberg's process has much control over bulk volume, bubble size, or other properties. However, hot, expanded perlite, while still plastic, might well be pressed into brick, slabs, and other shapes. The Cobrecite Corp., Detroit, has worked on a pumicite from near Cobre, Nev. to produce perlitic products trade-named "Cobrecite," and has patented some of them. In general, their products are made up of expanded grains bound together with a considerable percentage of voids between. Artificial pumice stones, colored by ceramic pigments to beautiful greens, blues, reds, and yellows and of convenient size for hand scouring, have been exhibited. Nevin and Kaloustian (15) patented for Cobrecite Corp. acoustic slabs made from volcanic glass (obsidian) or pumice fabricated to have many intercommunicating pores by mixing granules with sodium hydroxide as a binder in the ratio of about 10:1, and firing to 1,300°-1700° C. A similar product was patented by Kaloustian (15), in which pumicite is mixed with sodium hydroxide. As substitutes for sodium hydroxide there may be used soda ash, borax, and other alkaline fluxes, followed by firing at appropriate temperatures.

Acoustic Materials

In addition to the acoustic slabs of the Cobrecite organization mentioned above, an acoustic plaster was patented by Brookby (1). It consists of retarded gypsum stucco used with powdered oxalic or benzoic acid and granulated marble to further puff the plaster with gas bubbles generated when the mixture is wetted, and as the main body filler contains an aggregate of crushed pumice, perlite is doubtless a desirable substitute. The Fluftrok Corp., Reno, was reported in 1944-5 to be erecting a plant near Mason, Nev., to make perlite filler for a gypsum wallboard, using local gypsum (J. T. Benson, Bureau of Mines. Unpublished field report). An acoustical paint was patented by Roos, Offuth, and Scholz (19) and assigned to U. S. Gypsum Co. A mineral or vegetable fiber (such as mineral wool) is precoated with a farinaceous paste, such as starch, flour, gum arabic, casein, or sodium silicate solution, and mixed with granular pumice, gas-forming agents, a water-absorbent gum, and a preservative, ready to be mixed with water and applied to walls and ceilings as a sound deadener.

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Concrete Aggregate

This is the most obvious and potentially largest use of expanded perlite and related products. It seems superfluous to bolster this statement with references, but two foreign references show that the interest is not purely local, Perfetti (16) and Budnikov and Bobrovnik (2). For many years a rather heavy pumice has been used in constructing public buildings in Belgium to lighten the load on the steel portion of the structures, permitting use of less steel. Obviously a granule with glassy surface and sealed pores will not absorb water from the concrete mix and assures lightweight of the cured concrete. The remarks in an earlier section of this paper, about the strength of the granules and the need for research on making the best possible finished product, are pertinent. Many pumice granules have a proportion of open pores and upon standing will become waterlogged and sink in water, whereas well-prepared perlite granules float indefinitely.

During the recent war, a considerable amount of light-weight aggregate, mostly of bloated clay, was used in constructing concrete ships and barges. Also especially lightweight aggregate was wanted for construction of the "cushion" layers in concrete fortifications. Thick concrete roofs of air-dromes require very lightweight concrete to reduce the load to be supported and to keep destruction by bombing at a minimum. The spongy concrete absorbs the explosive force of a bomb by internal crunching and is not profoundly shattered and cracked like concrete made of solid granules. This localizes the effect of a bomb or shell.

Concrete blocks for building construction are so heavy as to require the service of two men in laying them, and the labor unions place a limit of 25 pounds per block for one-man laying. The popular sizes of concrete block weigh 40 pounds each if made with solid aggregate, but by substitution of light aggregate the weight can be reduced below the required maximum. Some use of pumice in such building block was made during the war in localities where pumice was conveniently available.

The ready-mix concrete associations have fought the introduction of lightweight aggregates because it will require doubling their investment in bins, one set for solid aggregates and one set for lightweight aggregates. The real economies possible in building construction are certain to overcome this opposition; or else new enterprisers, dealing entirely with lightweight materials, will set up competing establishments.

Thermal Insulation

Granular perlite can be used loose in many applications as for filling spaces around water heaters, refrigerators, and a wide variety of heating and refrigerating equipment. Which size or mixture of sizes gives the best insulation is not known and is a subject for future investigation.

Shapes like brick and slabs are also desirable in many applications, and some discussion of different means of forming them is given in a section above. (The use of mortars is also to be considered.) In boiler furnaces

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where a course of insulating brick is laid behind the refractory linings, there is a large use of various brick made up with diatomite, vermiculite and other lightweight thermal insulators that can resist fairly high temperatures.

Perlite has high promise for many of these uses (6,7), but only time will prove its exact usefulness and permit it to fill a definite niche in the various thermal technologies.

Porous Supports for Catalysts or Chemicals

The chemical industry has used lumps of pumice for decades to support catalysts and chemicals in gaseous reactions, scrubbing towers, and the like. As an example, the Companie Edouard Urbain (23) patented a pumice impregnated with iron salts and then calcined to leave them coated with iron oxides for trapping H_2S from gases like coke-oven gases.

Foundry Cores, Etc.

Lightweight cores of sufficient refractoriness to resist many nonferrous metals and cast iron have been made with perlite grain replacing the usual sand (6). This is an example of the many unanticipated uses of lightweight material that may come to light as wider advertising is given to the availability and properties of properly prepared perlite granules. Lightweight sand for water filtration should permit easier back-washing where the bed must be lifted and washed.

COMPETITIVE PRODUCTS

Perlite is merely a new product entering an established field now occupied by a number of mineral products like exfoliated vermiculite, pumice, bloated-clay granules, diatomite, mineral wool, and others. Perlite has the virtue of considerably more strength than most of these competitors and can be made in a variety of densities. It is fireproof and mildewproof (cork is not), does not attract water as vermiculite does nor disintegrate in moist conditions as mineral wool does, and can be made impermeable to water (vermiculite soaks up water and softens). There will undoubtedly be certain uses where each of the competitors finds a special field, but perlite promises greater versatility than any of them. Diatomite and vermiculite brick in furnace walls are more fragile, and salvage during rebuilding will be lower than is the case with perlite brick and slabs. Perlite is fairly resistant to many chemicals, and even with equal resistance a granule with glassy exterior presents less available surface for attack. Pumice of proper characteristics is too often found in remote locations, and the known deposits of perlite and pumice show that perlite is much more available to transportation in the Western States. Pumice can be improved by heat treatment similar to that which perlite requires.

Most of the open-hearth furnaces of the Nation are now provided with vermiculite insulation, either in the form of brick or of mortar. Some perlites have softening temperatures as high as those of vermiculite and therefore have the opportunity to compete.

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Loose-fill vermiculite in walls of structures that are quiescent can remain indefinitely, but on railroad cars and other structures slabs of vermiculite are preferable. A loose fill of the stronger perlite is not so likely to shake down if it is closely sized. Vermiculite attracts moisture and loses some of its insulating value, whereas perlite does not. In general, it would appear that in this field perlite has something more to offer. Mineral wool has to be protected against moist air attack by oiling the fibers; perlite does not.

PRODUCING PLANTS

Pumice in lumps and granules has been on the market for many years but has not been pushed before the public in the way that it might. The largest pumice producer is the Pumice Corp. of America, at Grants, N. Mex., which in 1939 produced 90,000 tons of pumice and pumicite (22). The Fluftrok Corp., office in Clay Peters Building, Reno, Nev. plant at Yerrington, Nev. near Mason, was mentioned in connection with gypsum wallboard above in the section on Bricks and Shapes. Wilson (24) reports the pioneer work of L. L. Royer on a perlite deposit near Superior, Ariz., and later (6) the Chemi-Cote Perlite Corp. was organized and set up improvised small plant equipment at Phoenix. The Continental Engineering Service, of Chula Vista, Calif. set up the Calite Corp. (5) at that town and in October 1945 was reported building its plant to process perlite mined near Las Vegas, Nev. Many other organizations are actively considering operations.

The above discussion reveals that so much more information is needed on perlite that lasting growth of the industry may prove slower than is desirable. Further research is necessary to put the industry on a firm foundation.

EXPLORATION OF PERLITE DEPOSITS

The record shows that numerous different siliceous volcanic glasses and rocks have perlitic behavior, so that little is known of the available resources of such material. The water content of each type of material varies, and the above discussion shows that not only must some estimate of amounts available of each material be made, but much research is necessary on their varying properties. The Bureau of Mines has examined a few of the deposits proved to have satisfactory perlitic behavior and made rough estimates of their available tonnages. Many more remain to be investigated, and samples should be taken and fired. This will be done as time and funds permit.

NEEDED TECHNOLOGIC RESEARCH

The Bureau of Mines has done desultory testing of various perlite samples at several of its experiment stations until the problem was better understood. The Tucson, Ariz. experiment station has recently organized this problem for research and will undertake investigations of the numerous factors mentioned in this circular.

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4/ Titles in parenthesis indicate translation from the original language.

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